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SUBJECT: Apollo Site Selection
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MEMORANDUM FOR FILE

As part of the effort to prepare for the Apollo Site Selection Board meeting, the attached document was prepared for Dr. R. A. Petrone to summarize the major factors which affect site selection for Apollo missions 15, 16 and 17. Topical sections cover accessibility, landability, science and photography. At Dr. Petrone's direction the document was distributed to all members of the Site Selection Board prior to its last meeting so that the outline of the document could serve as the basic structure for the meeting.

Members of Division 201 and others contributed to the preparation of the document, in particular, A. P. Boysen, Jr., T. B. Hoekstra, N. W. Hinnens and D. R. Anselmo.

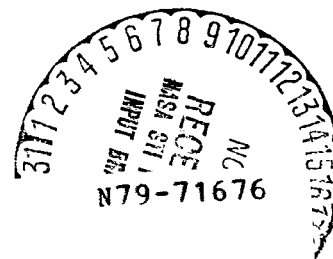
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Attachment

(NASA-CR-111174) APOLLO SITE SELECTION
FACTORS DOCUMENT (Bellcomm, Inc.) 28 p



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APOLLO SITE SELECTION FACTORS

INTRODUCTION

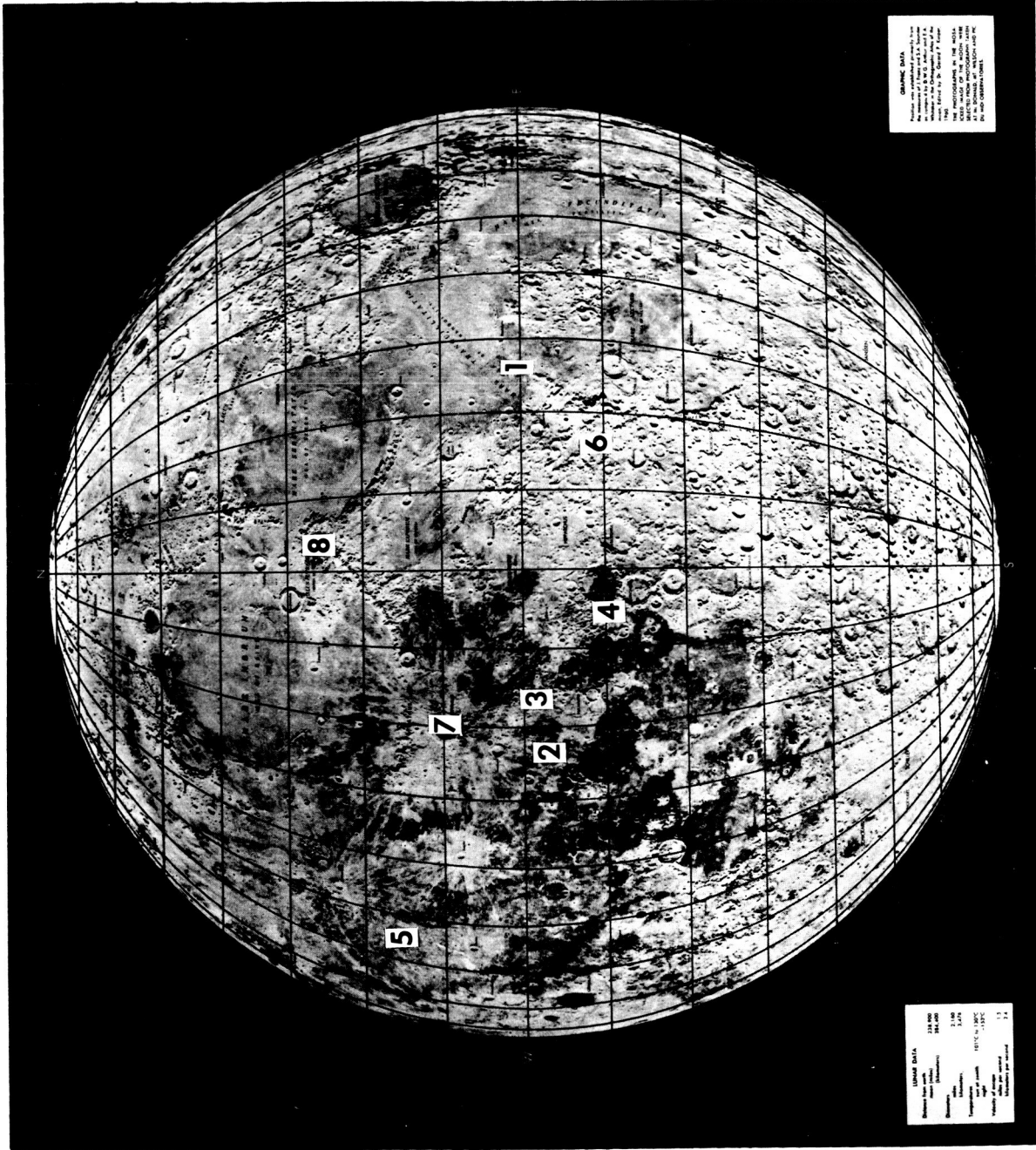
This memorandum attempts to summarize the major factors which affect site selection for the Apollo missions 15, 16 and 17. The topical sections are devoted to Accessibility, Landability, Science, and Photography. It is not the purpose to pre-judge the Apollo Site Selection Board (ASSB) decision, however the several factors involved do tend to narrow the available choices for Apollo 15 and 16.

In addition to the four topics noted above, there are several factors which influence site selection:

1. Through its most recent deliberations, the ASSB has implicitly indicated its willingness to consider certain candidate sites. These include Copernicus, Davy Crater Chain, Descartes, Hadley-Apennines and Marius Hills. Additional sites must have demonstrable scientific advantage to be considered.
2. For a variety of reasons, the site selected for one mission must not be totally dependent on or influenced by results from the immediately previous mission.
3. Apollo 15 is a rover mission. However, it is desirable that the Apollo 15 site be useful also as a walking mission. This mission must be chosen and structured with the realization that it is the first use of the Lunar Roving Vehicle (LRV); complete reliance on its satisfactory initial operation and utilization would not be the strongest possible position.
4. Launches are planned for January 1971, July 1971, January 1972 and June 1972. Sites should be accessible for the nominal launch date and at least for the two monthly windows following.
5. The surface science value and landability of a site are strong functions of the specific touchdown spot selected. Discussions of and decisions on landing sites must consider both the general regions and specific touchdown spots. Surface science objectives including experiment-specific factors should be given

APOLLO SITES

1. APOLLO 11
2. APOLLO 12
3. FRA MAURO
4. DAVY
5. MARIUS HILLS
6. DESCARTES
7. COPERNICUS
8. HADLEY



prime consideration in site selection. However, orbital science objectives also must be weighed. It is highly desirable to maximize areal coverage and minimize redundant coverage.

SUMMARY

Apollo 15 appears to be biased toward a choice between Hadley-Apennines and Marius Hills. Suitable photography is lacking for Descartes and Davy Crater Chain but is available for Copernicus. However, if Apollo 14 Descartes photography fails for any reason, Copernicus may become the prime "winter accessible" site (i.e. for Apollo 16). Further, depending on the specific landing point selected, a Copernicus mission appears to be more dependent on successful LRV operation than either a Marius Hills or Hadley-Apennines mission.

Marius Hills has some operational advantages over Hadley-Apennines. A Marius mission can provide, with good lighting (albeit setting-sun), photography of the highlands southeast of Descartes, an area of possible interest for Apollo 17. Such photography is a good backup for Apollo 14 photography, as well as of interest in itself. Additionally, Marius is accessible in October 1971 (the fourth month) while Hadley is not. This is of significance to Apollo 15 planning to assure flexibility in the event of LRV delivery delays.

Apollo 16 presents a choice between Descartes and Copernicus. Marius is not accessible; Hadley is marginally accessible; Davy photography is lacking. The strong scientific desire for highland samples leads one to favor Descartes, but successful Apollo 14 photography is required.

Apollo 17 may use one of the remaining sites or a new highland site. Use of Davy Crater Chain requires photography, the possibilities for which appear to be either an Apollo 15 mission to Marius Hills with photography of Davy with high ($\sim 60^\circ$) setting-sun illumination, or an Apollo 16 mission to Descartes five months before the Davy mission. A new highland site could be chosen either from presently available photography or from photography taken on Apollo 14 and 15.

It is not necessary to choose explicitly the Apollo 17 site now. No major work savings would result and it may be better to await the results of Apollo 14 and 15. Choices for Apollo 15 and 16 must, however, recognize and be tested in so far as possible for consistency with Apollo 17.

ACCESSIBILITY

The performance requirements for J-missions to the prime candidate sites have been computed in order to determine mission opportunities available with the Apollo Program Schedule recently announced by Dr. Paine. Table 1 summarizes the missions for which there are adequate fuel reserves.

Only the five sites currently approved by the ASSB are considered below, namely Copernicus, Davy Crater Chain, Descartes, Hadley-Apennines and Marius Hills. From performance considerations only, a Marius Hills mission for Apollo 16 is ruled out, and a Hadley Apollo 16 mission would be marginal. The nominal mission window is considered to extend over three consecutive monthly opportunities. However, the four consecutive months have been assessed for each mission to provide a feel for the implications of schedule slips.

The critical performance period for Apollo 15 occurs at the end of the sequence of monthly opportunities. The most difficult Apollo 15 mission considered would be to Hadley in October 1971 (see Table 3 discussed below). The landing would occur at 5° sun angle and TEI would have to occur shortly after LM rendezvous to maintain adequate SPS margins. Marius Hills Apollo 15 missions are feasible through October (with a little "tweaking" to raise the October SPS margin) with lighting at lunar landing in the 8°-12° range. Analysis of Marius Hills ground tracks during this period indicates that bootstrap photography of Davy, or Descartes, or highlands as far as 17° south could be obtained provided setting-sun photography is acceptable.

For the Apollo 16 mission, January through April 1972, Copernicus has adequate margins while Descartes has large enough ΔV margins to provide a good opportunity to obtain additional photography of southern highlands. The Hadley margins are small in January and February, but should other sites become unavailable for Apollo 16, a reduced-duration mission could be flown to Hadley.

The earliest month for the Apollo 17 mission is June 1972, so performance was checked through September. All five sites have adequate ΔV margins throughout this period. The regions of the moon in which potential landing sites could be reached during the Apollo 17 mission period are indicated schematically on Figure 1.

The design of the mission trajectories must be performed subject to several operational constraints which substantially affect lunar site accessibility. The reference

TABLE 1 - ACCESSIBILITY SUMMARY

	1971					1972									
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
MARIUS HILLS	●	●	●	●	▨	▨					▨	●	●	●	●
DESCARTES	●	●	●	●	▨	▨	●	●	●	●	▨	●	●	●	●
HADLEY	●	●	●		▨	▨	○	○	●	●	▨	●	●	●	●
COPERNICUS	●	●	●	○	▨	▨	●	●	●	●	▨	●	●	●	●
DAVY CRATER CHAIN	●	●	●	●	▨	▨	●	●	●	●	▨	●	●	●	●
	← APOLLO 15 →					← APOLLO 16 →					← APOLLO 17 →				

- FEASIBLE MISSION OPPORTUNITY
- FEASIBLE ONLY WITH REDUCED LUNAR ORBIT STAY
- NOT CONSIDERED

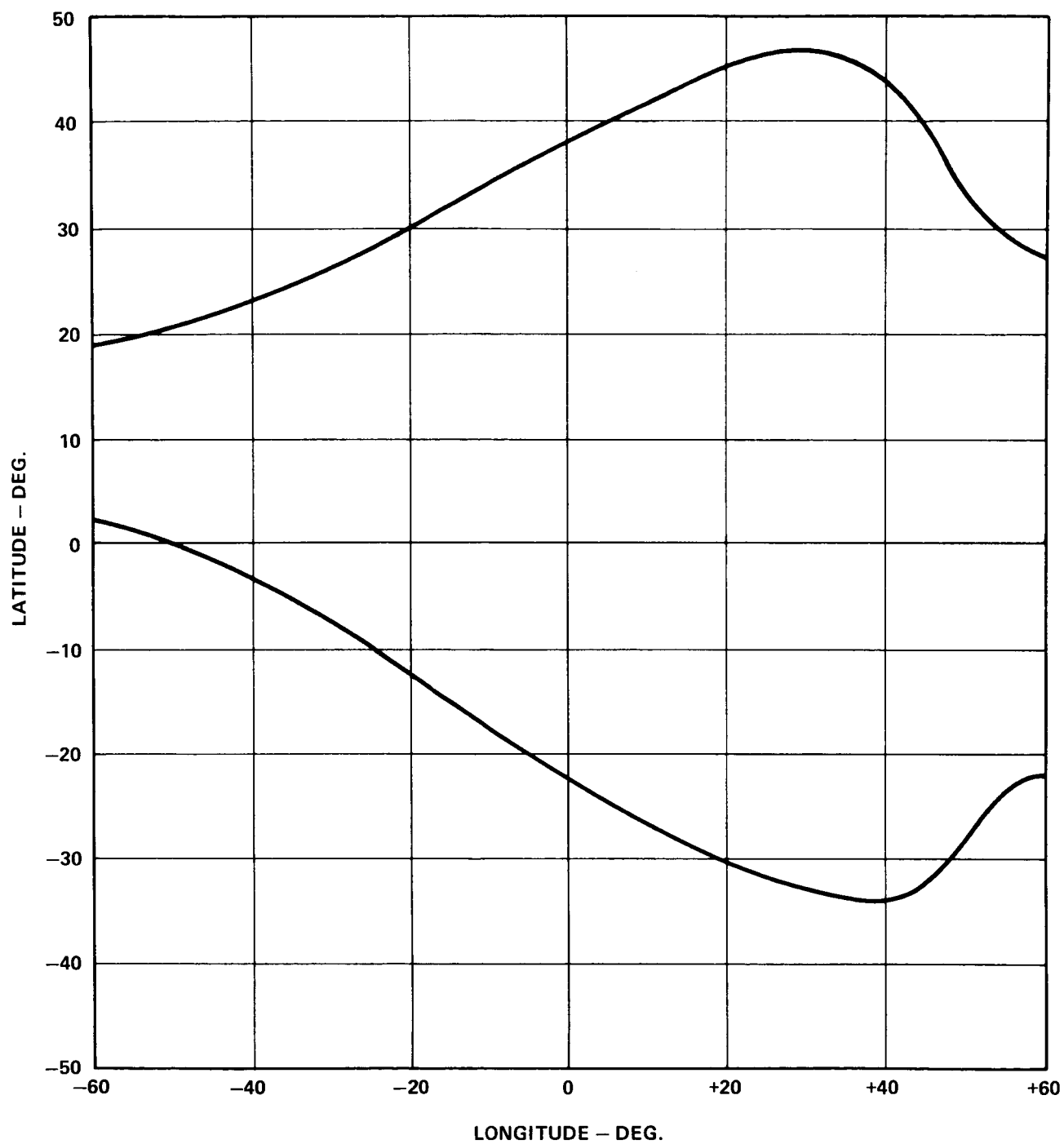


FIGURE 1 LUNAR ACCESSIBILITY FOR THE SUMMER OF 1972

mission used to generate the attached data consists of a relaxed free return profile with landing on the moon at sun elevations between 5 and 14 degrees. The timeline has a 66-hour lunar surface stay and a total of 173 hours in lunar orbit (sufficient for series orbital science). Mission durations up to 14.5 days were allowed. A complete list of mission constraints which define the reference mission is given in Table 2. A 107,300 lb total spacecraft weight was assumed (66,900 lb CSM with full SPS tanks and 36,300 lb LM).

Table 3 is a summary of the launch vehicle and spacecraft propulsion capability excluding some which are ruled out by other considerations. These data are preliminary and should be used primarily to make relative comparisons since the actual numerical values are quite sensitive to the constraints assumed. The launch vehicle capability at TLI is determined by adding to the MSFC baseline payload commitment (106,600 lbs) the payload correction for wind and temperature monthly variation, the flight geometry reserve and the mission-specific energy variation. If the launch vehicle capability for a site in a particular month exceeds the 107,300 lbs spacecraft weight, the SPS tanks could be flown fully loaded. However, depending on the SPS margin for that mission, it may be desirable to off-load some SPS propellant to increase the overall probability of mission success. If the launch vehicle capability falls below 107,300 lbs, the SPS must be off-loaded to fly the mission. The contingency ΔV available shown in the attachment is the end-of-mission SPS margin assuming the SPS is loaded either to the launch vehicle capability or full (whichever is less). Normally a reserve of 500 fps is desirable for weather avoidance, but this may be relaxed to 250 fps if necessary. Also, it must be possible to raise the contingency ΔV to 600 fps for LM rescue by altering constraints if need be, i.e., shorten lunar orbit stay, increase transearth coast time or relax return inclination. The contingency ΔV available (or SPS margin referred to above) is the principal parameter which determines the feasibility of a given mission.

Table 2

"J" MISSION DESIGN CONSTRAINTS

Mission Design Constraints

- Only Pacific translunar injections are considered.
- Launch azimuth = 72 degrees.
- Earth orbit altitude = 90 NM.
- 40 Hr. \leq translunar flight time \leq 110 hr.
- 40 NM \leq perilune altitude of incoming hyperbola \leq 60 NM.
- A relaxed free return translunar trajectory is used.
- A DPS abort is possible at least two hours after perilune.
- DOI is performed by the SPS.
- The time in orbit from lunar orbit insertion to LM landing is approximately 26 hours.
- The lunar surface staytime is 66 hours.
- The time in lunar orbit from CSM-LM rendezvous to transearth injection is approximately 82 hours.
- 45 Hr. \leq transearth flight time \leq 120 Hr.
- The return geographic inclination relative to the earth's equator is less than 40 degrees.
- $-35^{\circ} \leq$ earth landing latitude $\leq 35^{\circ}$.
- $-170^{\circ} \leq$ earth landing longitude $\leq -150^{\circ}$ (Pacific zone).
- The maximum mission duration is 14.5 days.

TABLE 3

PERFORMANCE CAPABILITY SUMMARY

APOLLO 15 1971				APOLLO 16 1972				APOLLO 17 1972									
		JULY	AUGUST	SEPT	OCT	JAN	FEB	MARCH	APRIL	JUNE	JULY	AUGUST	SEPT				
MARILLUS HILLIS	LAUNCH VEHICLE CAPABILITY-LBS	107970	108070	108060	107870	NOT FEASIBLE - SPS								107690	107790	107920	107960
	AVAILABLE CONTINGENCY ΔV-FPS	1330	970	660	220	CAPABILITY INSUFFICIENT								1250	1370	1120	860
DESCARTES	LAUNCH VEHICLE CAPABILITY-LBS	ADEQUATE PHOTOGRAPHY				107430	107140	107290	107220	107420	107640	107660	107700				
	AVAILABLE CONTINGENCY ΔV-FPS	LACKING				1040	1170	1190	1160	1380	860	790	630				
HADLEY	LAUNCH VEHICLE CAPABILITY-LBS	107640	107460	107400	107370	107100	106940	107030	107110	107360	107570	107590	107360				
	AVAILABLE CONTINGENCY ΔV-FPS	1230	820	370	10	-20	60	360	730	1270	1290	1070	650				
COPERNICUS	LAUNCH VEHICLE CAPABILITY-LBS	BETTER CHOICE FOR A LATER MISSION				107260	107170	107140	107260	107650	107610	107790	107690				
	AVAILABLE CONTINGENCY ΔV-FPS					550	640	830	1040	1530	1320	1110	770				
DAVY	LAUNCH VEHICLE CAPABILITY-LBS	ADEQUATE PHOTOGRAPHY LACKING				ADEQUATE PHOTOGRAPHY LACKING								107530	107490	107670	107510
	AVAILABLE CONTINGENCY ΔV-FPS													650	510	470	300

NOTE: PERFORMANCE NUMBERS ARE BASED ON CONIC GENERATED TRAJECTORIES UNDER CONSTRAINTS LISTED IN TABLE 2.

LANDABILITY

The prime landing spot is an area chosen for its scientific potential, suitable for landing safely, and for which the EVA activities can be planned. Easily recognizable landmarks near the site are desirable so the crew can quickly and reliably locate the prime spot visually, and alter the trajectory appropriately to reach it. Each mission can be treated as a "pinpoint landing mission" in that the crew will make every reasonable effort to reach the prime spot if they can locate it.

The landing dispersion area is of prime importance in planning the strategy of the landing approach. Assuming the last guidance update (Δ RLS) is made near ignition (PDI)*, this dispersion area is elliptical in shape with semi major axes of approximately +3300 ft downrange and +4500 ft cross-range at the 99% probability level. Within this area, for the case where the crew fails to locate the prime spot visually or feels it improper to alter the trajectory enough to reach it, there must be at least a small number of suitable alternative landing spots. The "N" numbers for the ellipse are not necessarily indicative of acceptability and may be small; more direct analysis of the area than simply an "N" number calculation is required to determine if alternative spots are available.

With the current trajectory, shown in Figure 2, the approach terrain to the area must lie below a line originating at the landing site with an 8° slope uprange. This is required both to insure that dispersed trajectories clear the terrain and to avoid too much shadowing of the area at low sun angles. Steeper descent trajectories can be designed (probably with some additional propellant cost) to permit landings closer to peaks and ridges under the approach path. The five prime sites all have significant terrain features east of the desirable landing areas. If current LMS simulations of steep descents (up to 30° glide slope) prove satisfactory, if the propellant penalties were judged acceptable, and if the decision were made, the landable regions could be expanded at each site.

Given a terrain feature of a certain height, Figure 3 shows how close the landing site can be to that feature, with 8° maintained between the approach phase glide slope and the terrain slope (see sketch on Figure 3). This is calculated

*A reasonable assumption since there are three equally valid sources for the number, and since no site under present consideration is so situated that insufficient time is available for the Δ RLS update.

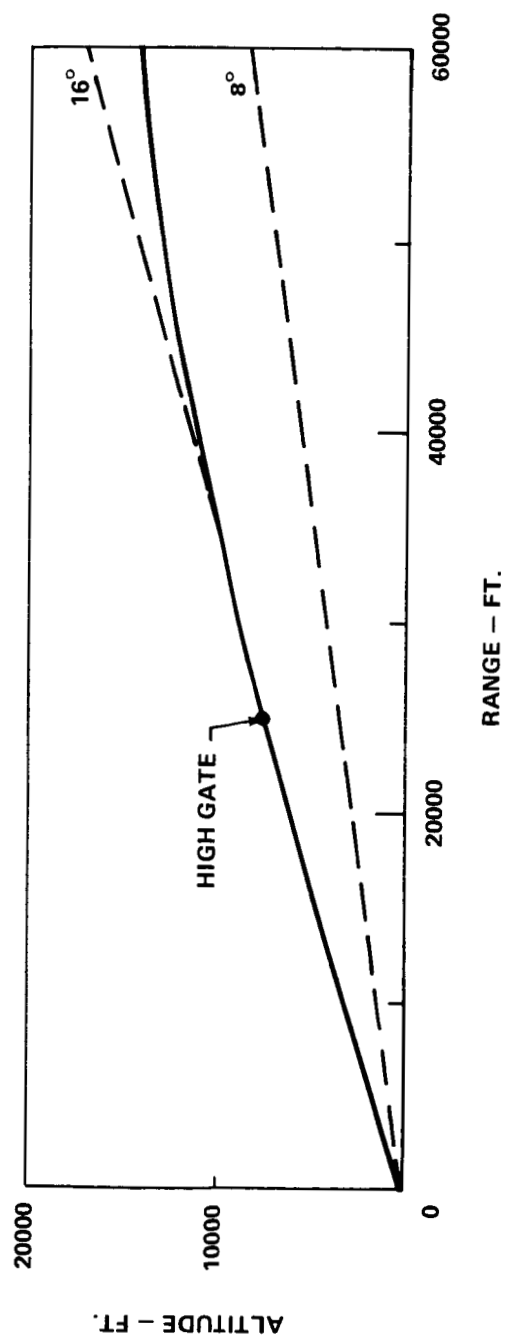


FIGURE 2 - LM DESCENT PROFILE

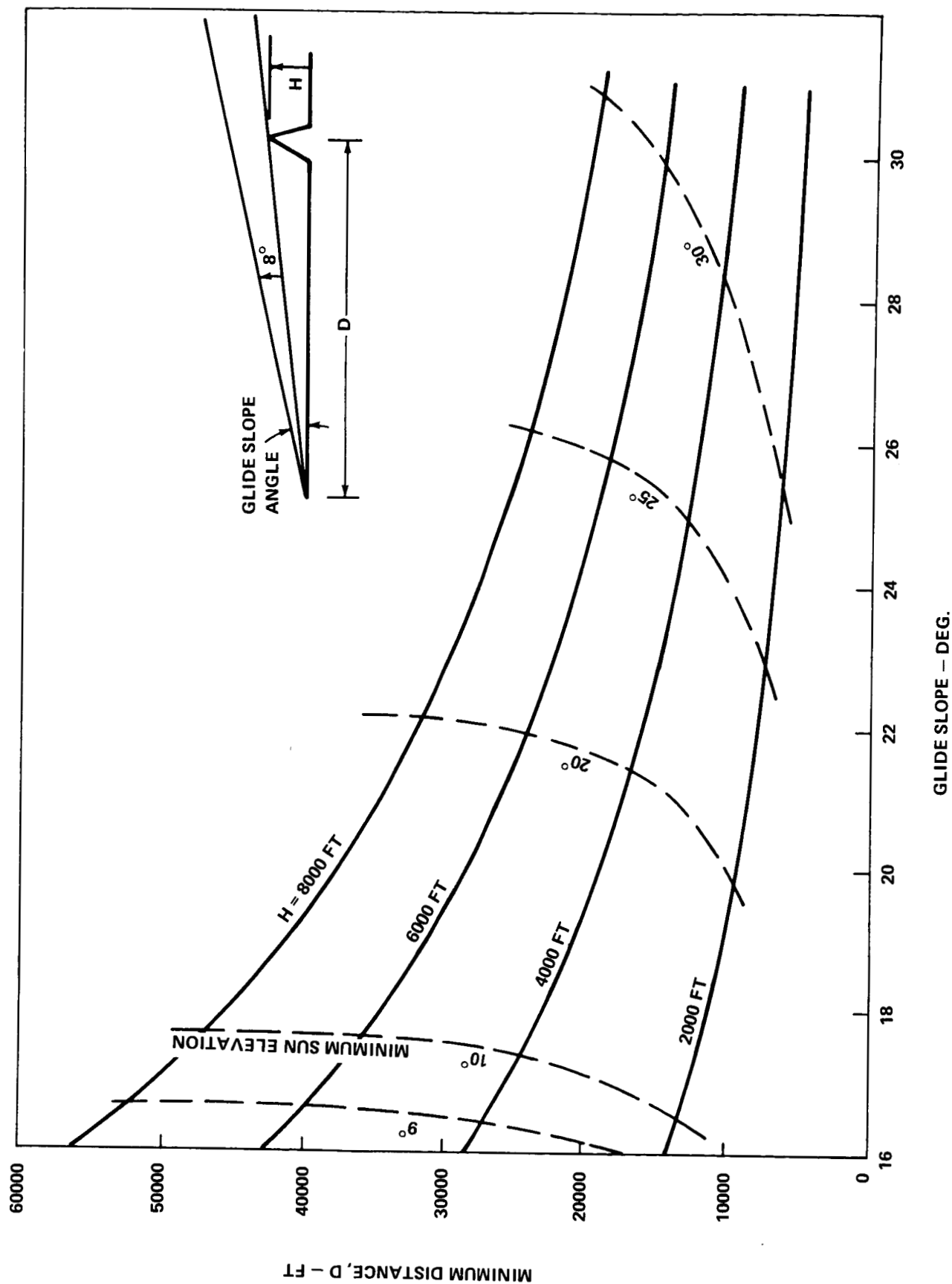


FIGURE 3 - MINIMUM DISTANCE FROM OBSTACLE TO LANDING SITE FOR VARIOUS GLIDE SLOPE ANGLES.
 This assumes that the trajectory clears the terrain by 8°. The dashed lines show the sun angle which places the edge of the shadow of an obstacle 2000 ft. uprange of the site when the minimum D is used.

for the range of glide slopes under present consideration. Also shown is the minimum sun angle needed to keep shadows from such a feature at least 2000 ft from the landing site.

Stereo photography is needed to produce an approach terrain model to be used in the LM guidance computer. This terrain model makes possible much more effective use of the landing radar information. However, it is necessary that the effect of reasonable dispersions in the actual flown trajectory (in azimuth, downrange and crossrange placement relative to the lunar surface) not defeat the intent of the terrain model. There is thus an implicit constraint on the roughness of the terrain along and underneath the approach path.

Hadley-Apennines

The Hadley site (Figure 4) which was considered for a walking mission on H-4 appears acceptable from a landing standpoint. The approach terrain is only a weak function of approach azimuth and crossrange navigation errors and can be handled adequately by the "a priori" LM terrain model. The 8000 ft maximum elevation of the ridge east of Hadley is about 60,000 ft from the site so the minimum sun elevation angle is about 8°.

The double craters adjacent to the site, the ridge to the south of the site, and the rille to the west provide excellent landmarks for early crew recognition of navigation errors at high gate.

Sites within the high resolution Hadley photography (north of the proposed H-4 site) appear to be suitable only for rover missions if the ridge east of the rille is to be visited. To assure adequate terrain clearance the site would have to be chosen in the southwest corner of the mare east of Hadley rille covered by high resolution photography. With an Apollo 14 type trajectory, the site could not be closer than about 20,000 ft west of the base of the Hadley front.

Marius Hills

From an approach terrain and landmark standpoint, there have not been made strong distinctions between Hadley and Marius Hills. For approaches to the central landing site at Marius (Figure 5), the two eastern hills (about 1200 ft high, 12,000 ft uprange of the site) make the terrain somewhat azimuth and navigation error dependent but for no azimuth has it been judged unacceptable. The western hills provide good landmarks during the approach phase.

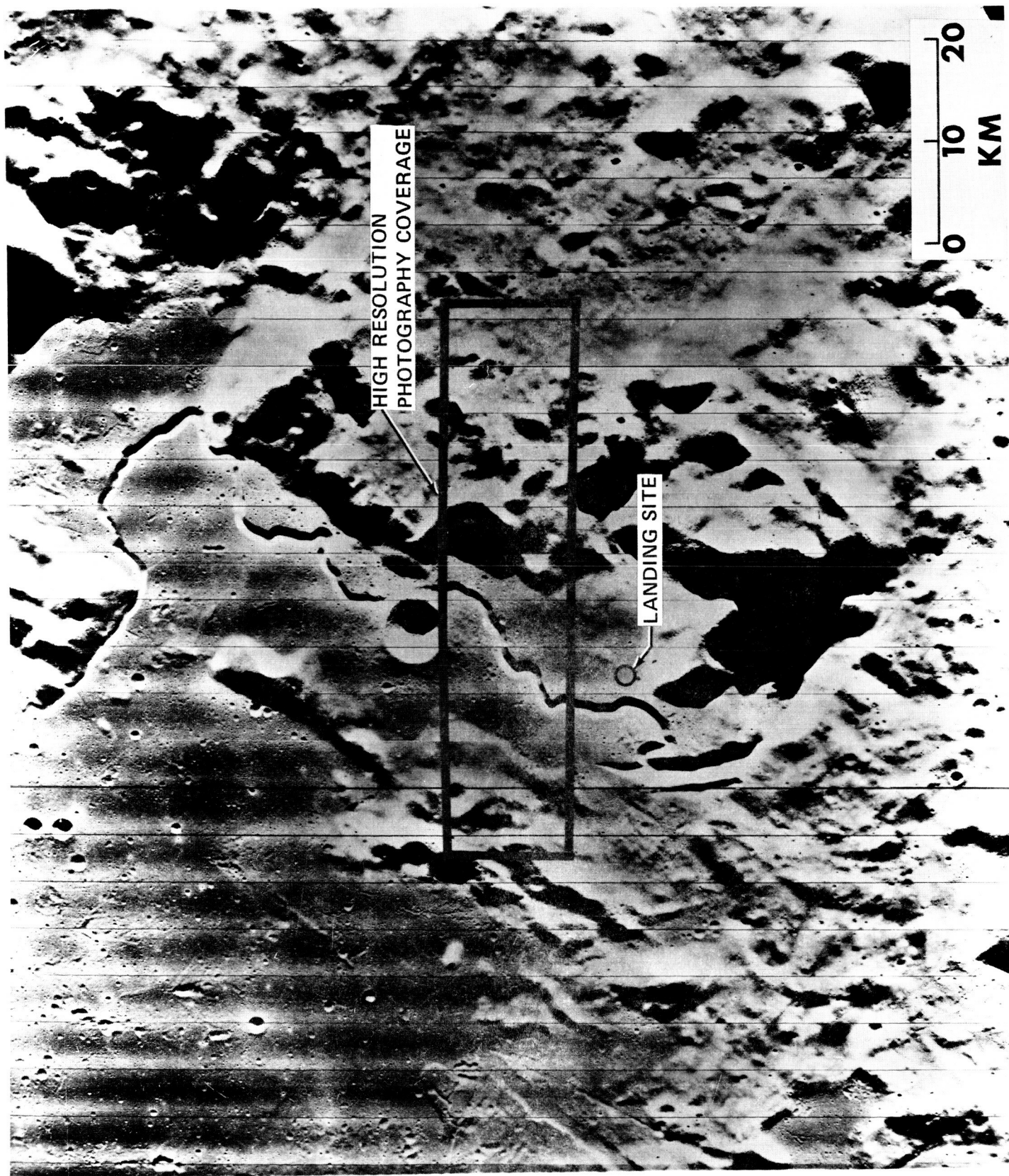


FIGURE 4 - HADLEY-APENNINES



FIGURE 5 - MARIUS HILLS

Copernicus

With the LM terrain model available in the computer, the crater wall at Copernicus (Figure 6) appears not to present a problem for landings in the central peaks region. The central peaks themselves make landability a strong function of the choice of site and approach azimuth. The maximum elevation of the central peaks is about 3000 ft; a landing site should not be closer than about 20,000 ft downrange of such a peak with the current trajectory.

The rover site to the north ($19^{\circ} 55' W$, $9^{\circ} 45' N$) of the peaks appears to be acceptable from a landing standpoint for azimuths within $\pm 30^{\circ}$ of due west. The small peak west of the site provides a possible good landmark for the approach phase.

Davy Crater Chain

The approach at Davy Crater Chain (Figure 7) is similar to that at Hadley. Although detailed terrain data is not available, preliminary analysis indicates that the ridge east of Davy Crater Chain is about 2000 ft high. With the current trajectory the landing site would have to be at least 14,000 ft downrange of the top of the range. Sensitivity to crossrange errors should be small.

The crater chain at Davy provides an excellent series of landmarks for landing site location.

Descartes

Landability at Descartes (Figure 8) is a function of the specific landing area desired. Orbiter IV and Apollo 12 photography need further analysis to support the selection of an acceptable site.

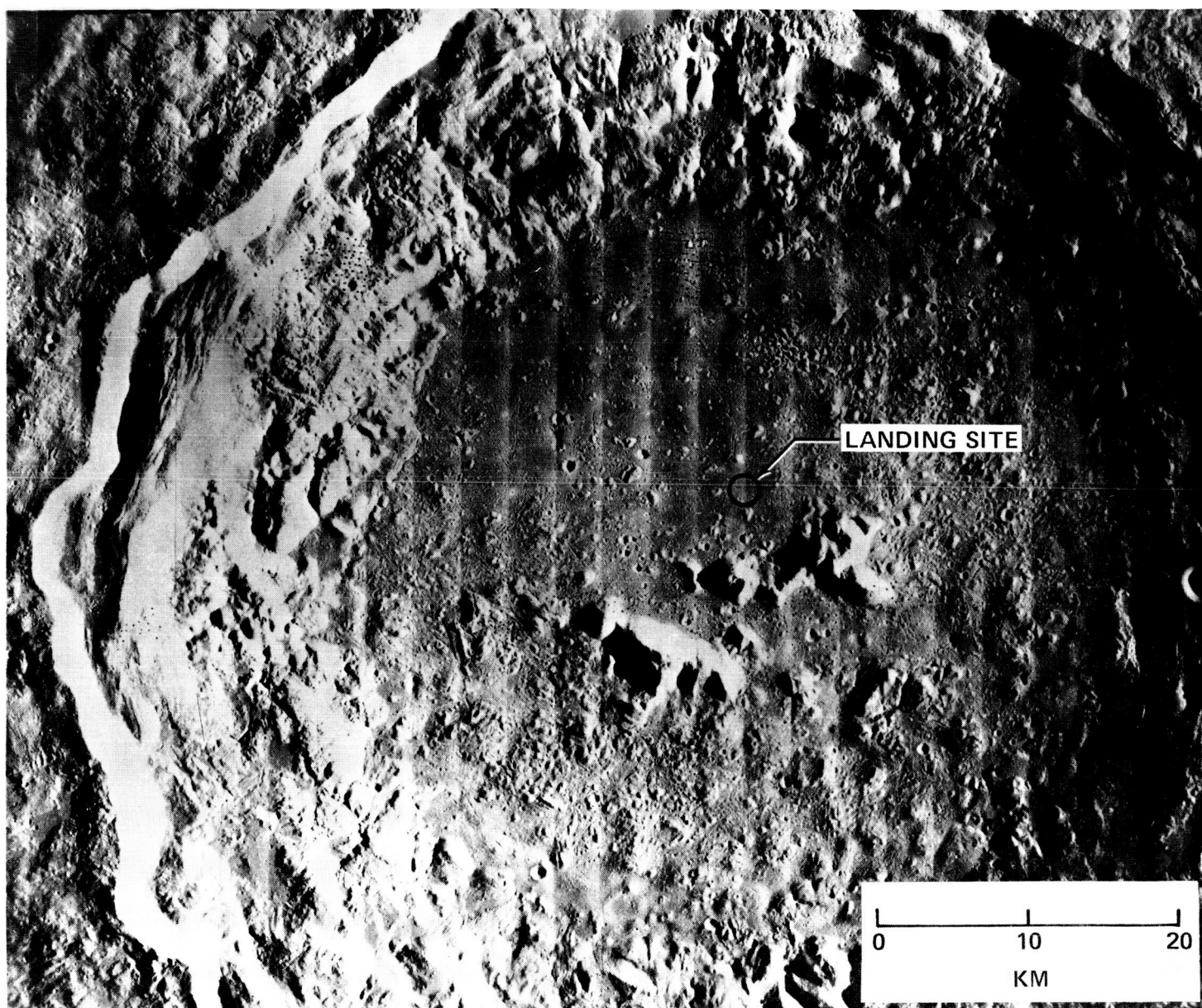


FIGURE 6 - COPERNICUS PEAKS

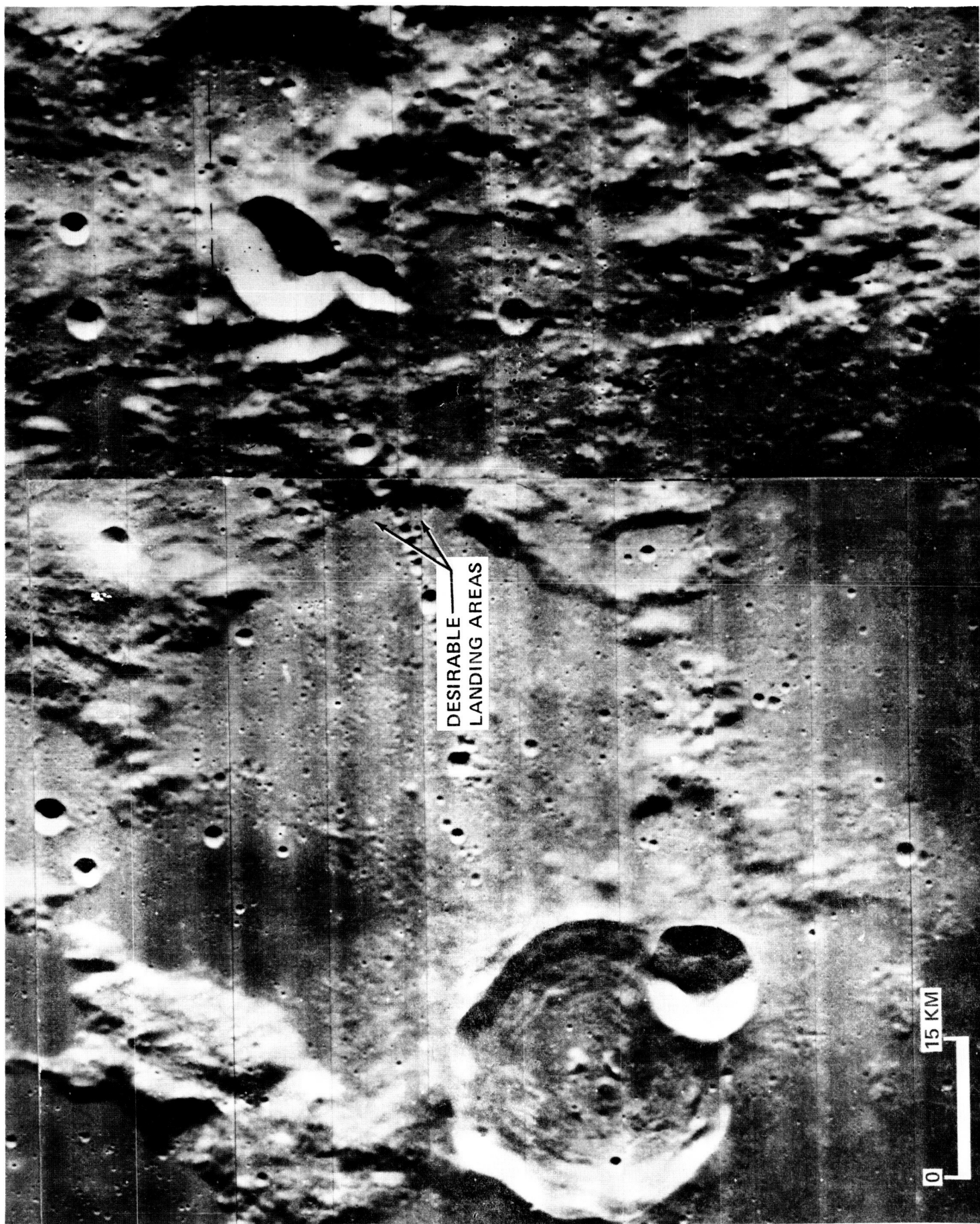


FIGURE 7 - DAVY RILLE

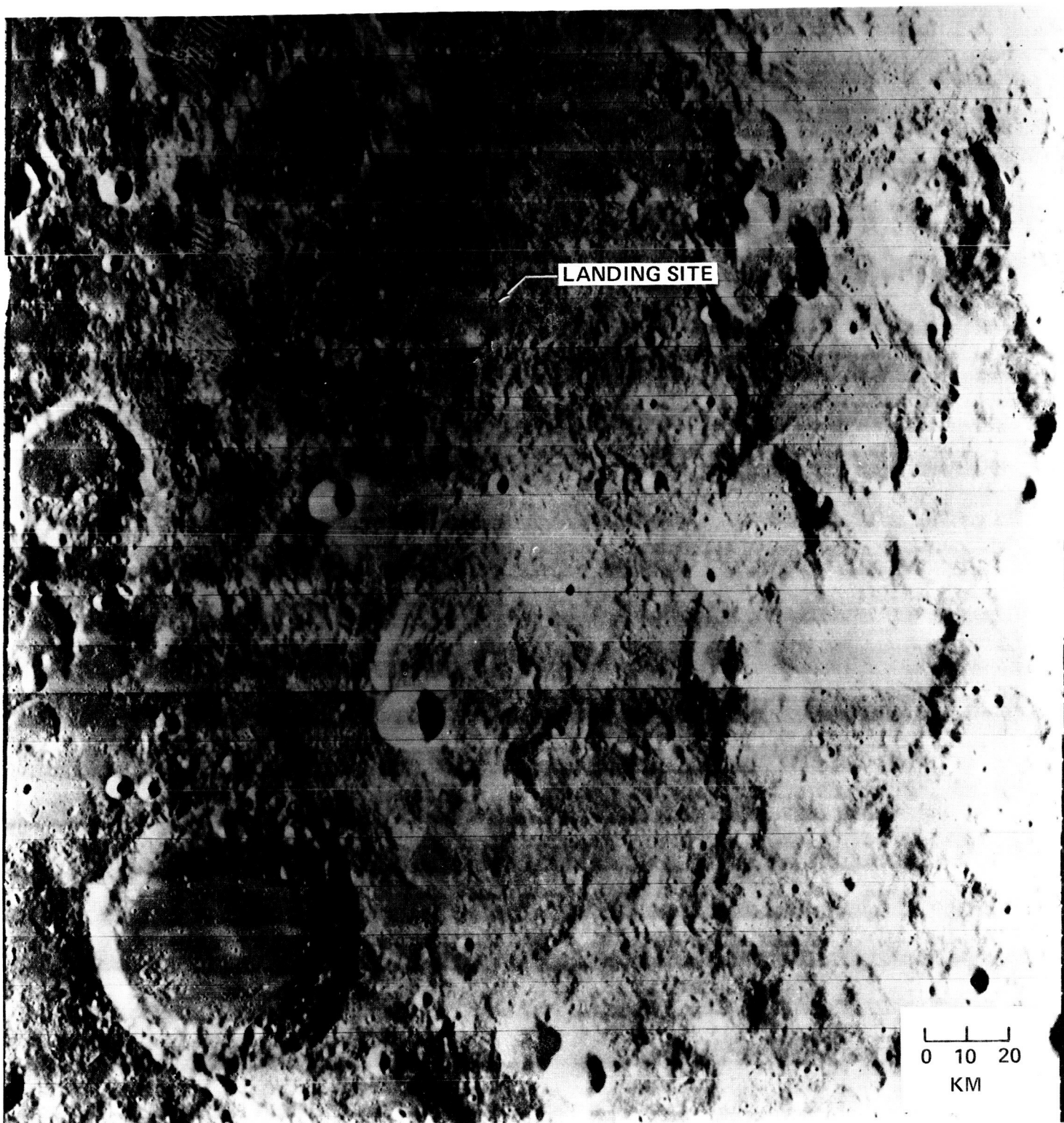


FIGURE 8 - DESCARTES

SCIENCE

Site Scientific Rationale

A basic objective of the Apollo Program is to establish the chronology of major events, the compositional makeup and variation of the lunar surface, interior and atmosphere, the types of processes at work now or in the past, and the internal structure and energy regimes of the moon. The Apollo 11 and 12 missions established ages of mare basin fill and a successful Apollo 14 mission will yield a fix on the chronology of mare basin formation. The Program must now establish the highlands (e.g., Descartes) and young or post-mare (e.g., Marius Hills, Copernicus) time scales.

Significant compositional data on mare fill now exists. The Program must now acquire, as a top priority, highland samples (e.g., Descartes) and sub-surface materials (e.g., Copernicus, Davy Crater Chain).

Volcanic activity has been recognized as a major process resulting in mare filling. It is now necessary to investigate highlands volcanism (Descartes) and desirable to investigate extremes of marial volcanism (Marius Hills). Rille formation, an enigma, can be studied at Hadley-Apennines. The role of meteoroid impacts as a topographic modifier has been demonstrated. It remains to explore a set of sites of different ages (e.g., Marius Hills, Descartes, Davy Crater Chain) to establish the meteoroid time-flux history and to investigate a large impact site with associated volcanism (Copernicus).

The geophysical experiments (seismometer, magnetometer) have begun to return significant data on the structure and energy of the upper tens to hundreds of kilometers of the lunar interior. It is necessary now to complete the establishment of geophysical nets with particular regard to highlands (e.g., Descartes) and highlands-mare boundaries (e.g., Hadley-Apennines) and to implement the heat flow experiment as a major complement to the seismic and magnetic stations. A spread in longitude and latitude is highly desirable for certain experiments (e.g., LR³).

The orbital remote sensing experiments must now obtain data to allow extrapolation of ground-truth data from surface experiments and returned samples. A landing site in the far west and one in the far east are needed to provide favorable lighting conditions to extend photography around both limbs. This is required to obtain backside photography and to extend metric control to allow better determination of the figure of the moon. Sites of high inclination are desired in order to maximize surface coverage.

Copernicus Peaks

Copernicus is a relatively young, very large bright-rayed probable impact crater approximately 95 km in diameter and located just south of Mare Imbrium. A mission to the floor of the crater Copernicus, 4 km below the crater rim, would have as its primary objectives the examination of the central peaks and the crater floor material. The central peaks, which rise up to 800 meters from the crater floor, probably represent deep-seated material, which is of importance in determining the internal characteristics of the moon and in complementing the mare samples obtained on Apollo 11 and 12. Examination of the domes and textured material of the crater floor will provide an understanding of the process of crater floor filling and help clarify the role of volcanism in post-event crater modification. Age determinations of the central peak material, the cratering event, and the subsequent crater fill material will provide a time scale of importance in understanding the origin and modification of large impact craters and in establishing the relatively recent flux of meteoroids.

Davy Crater Chain

Davy Crater Chain is a probable volcanic crater chain crossing the highlands west of Ptolemaeus and the floor of the old basin Davy Y, northwest of the crater Alphonsus. The major objective of a mission to Davy is sampling and investigation of this segment of the lunar central highlands, which is far enough from Mare Imbrium not to be mantled with a substantial thickness of the Imbrium ejecta. A second objective is to sample and investigate one or more of the craters which make up the 60 km Davy Crater Chain. Since the craters forming the Davy Crater Chain appear to be analogous to terrestrial maar-type volcanic craters which often bring up deep mantle fragments, an objective of this landing site concerns the acquisition of material from deep within the lunar interior. It is such material which may be the parent or source rock of the lava filling the maria and which was sampled on Apollo 11 and 12. A landing near the point where the crater chain crosses into the highlands should also provide samples of the plains material on the floor of Davy Y, or of similar plains forming units on the western Ptolemaeus highlands. Acquisition of these materials will provide data on the physical properties of the lunar interior as well as on the characteristics and age of widespread geologic units.

Descartes

The Descartes landing site lies in the central lunar highlands several hundred kilometers west of Mare Nectaris, and is the site of hilly, grooved and furrowed terrain which

is morphologically similar to many terrestrial areas of volcanism. The Descartes area is also the site of extensive development of highland plains material, a geologic unit of widespread occurrence. The primary objectives of a mission to the site would be the examination and sampling of a highland volcanic complex and the plains material. Knowledge of the composition, age, and extent of magmatic differentiation in the highlands will be particularly important in understanding lunar volcanism and its contribution to the evolution of the lunar surface and interior. Comparison of this putative highland volcanic complex to mare volcanic complexes such as Marius Hills will provide a sample of a wide spectrum of lunar volcanic activity. An understanding of the composition and age of the highland plains material will add to our knowledge of the processes which modify large areas of the lunar highlands. It will be of special significance in determining the early meteoroid flux.

Hadley-Apennines

The Apennine Mountains rise up to 2 km above the surface of Palus Putredinis and might contain ancient material exposed during the excavation of the Imbrium basin. Sampling of such Apenninian material should provide very ancient rocks whose origin predates the formation and filling of the major mare basins. Rima Hadley is a V-shaped lunar sinuous rille which parallels the Apennine Mountain front along the eastern boundary of Mare Imbrium. The rille originates in an elongate depression in an area of associated volcanic domes and generally maintains a width of about 1 km and a depth of 200 meters until it merges to a second rille approximately 100 km to the north. The origin of sinuous rilles such as Rima Hadley is enigmatic but is probably due to some type of fluid flow. The determination of the nature and origin of a sinuous rille and its associated elongate depression and process may yield data on the history of lunar volatiles.

Marius Hills

The Marius Hills are a series of domes and cones located northwest of the crater Marius near the center of Oceanus Procellarum. The morphologic units which comprise these hills are analogous in form and sequence to terrestrial volcanic complexes which display a spectrum of rock compositions and ages. The various geologic units suggest that a prolonged, but relatively recent, period of volcanic activity has occurred in the Marius Hills area and that magmatic differentiation has produced a spectrum of rock types and a series of volcanic landforms displaying characteristic structural relationships.

Therefore, the primary objectives of a mission to the Marius Hills are to study the spectrum of geologic units in order to establish the extent and age of possible magmatic differentiation and to determine the structural relationships of volcanic land-forms in the maria.

Surface Science

Table 4 summarizes current plans for the assignment of lunar surface experiments to the remaining Apollo missions. Experiment assignments to Apollo 14 can be considered firm at this time. It is likely that gravimetric experiments, such as S-199 (Traverse Gravimeter) and S-206 (Tidal Gravimeter), would not be available until Apollo 17.

Orbital Science

Table 5 presents a similar summary for orbital science and other in-flight experiments. The need for early planning to integrate the orbital science experiments with the Service Module structure makes their potential re-assignment less flexible than the lunar surface experiments. Designs for Lunar Sounder experiments are in the exploratory phase at this time and these experiments probably cannot be ready prior to Apollo 17.

It should be noted that the first two J-series flights have identical payloads and should have orbital inclinations which minimize redundant coverage. All these missions have high resolution panoramic and metric camera systems, and can provide maximum benefit through high inclination orbits to increase areal coverage. A landing site in the far west and one in the far east would provide lighting conditions to extend photography around both limbs to maximize lunar backside photography, and to extend metric control to obtain a better knowledge of the figure of the moon.

Figure 9 depicts post-rendezvous orbital photographic coverage for four of the sites. Note that Marius provides maximum western backside lunar coverage for lunar orbital photography but covers most of the area which would be available on a subsequent mission to Copernicus. A Hadley flight provides maximum orbital science coverage due to its high inclination orbit, and perhaps should be considered a primary mission for orbital science. The Descartes site provides maximum extension of orbital photography and science around the eastern limb.

LUNAR SURFACE EXPERIMENTS

	APOLLO 14	APOLLO 15	APOLLO 16	APOLLO 17
S-059 LUNAR GEOLOGY INVESTIGATION	A	A	A	A
S-078 LASER RANGING RETRO-REFL. (100-CUBE)	A			
S-078 LASER RANGING RETRO-REFL. (300-CUBE)		C OR	C OR	C
S-080 SOLAR WIND COMPOSITION	A			
S-152 COSMIC RAY DETECTOR (SHEETS)		A		A
S-198 PORTABLE MAGNETOMETER	A		A	A
S-199 TRAVERSE GRAVIMETER				A
S-200 SOIL MECHANICS	A	A	A	A
S-201 FAR UV CAMERA/SPECTROSCOPE				A
S-204 SURFACE ELECTRICAL PROPERTIES				
S-031 LUNAR PASSIVE SEISMOLOGY	A	A	A	B
S-033 LUNAR ACTIVE SEISMOLOGY	A		A	
S-034 LUNAR TRI-AXIS MAGNETOMETER		A	A	
S-035 MEDIUM ENERGY SOLAR WIND		A		
S-036 SUPRATHERMAL ION DETECTOR	A	A		
S-037 LUNAR HEAT FLOW (WITH DRILL)		A	A	A
S-038 CHARGED PARTICLE LUNAR ENV.	A			
S-058 COLD CATHODE IONIZATION GAUGE	A	A		
S-202 LUNAR EJECTA AND METEORITES				A
S-203 LUNAR SEISMIC PROFILING				A
S-205 LUNAR ATMOS. COMPOSITION				A
S-206 TIDAL GRAVIMETER				B
M-515 LUNAR DUST DETECTOR	A	A		

ALSEP

A-ASSIGNMENT CURRENTLY PLANNED
 B-EITHER S-031 OR S-206 WILL BE FLOWN
 ON APOLLO 17
 C-UNDER CONSIDERATION

TABLE 4

LUNAR ORBITAL, IN-FLIGHT, AND PRE- & POST-FLIGHT EXPERIMENTS

	APOLLO 14	APOLLO 15	APOLLO 16	APOLLO 17
S-160 GAMMA-RAY SPECTROMETER				
S-161 X-RAY SPECTROMETER		A	A	C
S-162 ALPHA PARTICLE SPECTROMETER		A	A	
S-164 S-BAND TRANSPONDER (CSM/LM)	A	A	A	A
S-165 MASS SPECTROMETER		A	A	
S-169 UV SPECTROMETER				A
S-170 BISTATIC RADAR	A	A		
S-171 IR SCANNING RADIOMETER				A
SUBSATELLITE:				
S-173 PARTICLE SHADOWS/BOUNDARY LAYER		A		A
S-174 MAGNETOMETER		A		A
S-164 S-BAND TRANSPONDER		A		A
S-176 APOLLO WINDOW METEOROID	A	A		
S-177 UV PHOTOGRAPHY-EARTH AND MOON		A	A	
S-178 GEGENSCHIEIN FROM LUNAR ORBIT	A	A		
S-167 LUNAR SOUNDER A	A COMBINED EX-PERIMENT WILL BE DESIGNED			C
S-168 LUNAR SOUNDER B.				C
T-029 PILOT DESCRIBING FUNCTION	A	A	A	A
M-078 BONE MINERAL MEASUREMENT	A	A	A	A
M-079 TOTAL BODY GAMMA SPECTROMETRY		A*	A*	A*

A - ASSIGNMENT CURRENTLY PLANNED

C - UNDER CONSIDERATION

A* - ASSIGNED PENDING ELIMINATION OF QUARANTINE REQUIREMENTS

APOLLO LUNAR ORBITAL SCIENCE J MISSION PHOTOGRAPHIC COVERAGE PRELIMINARY

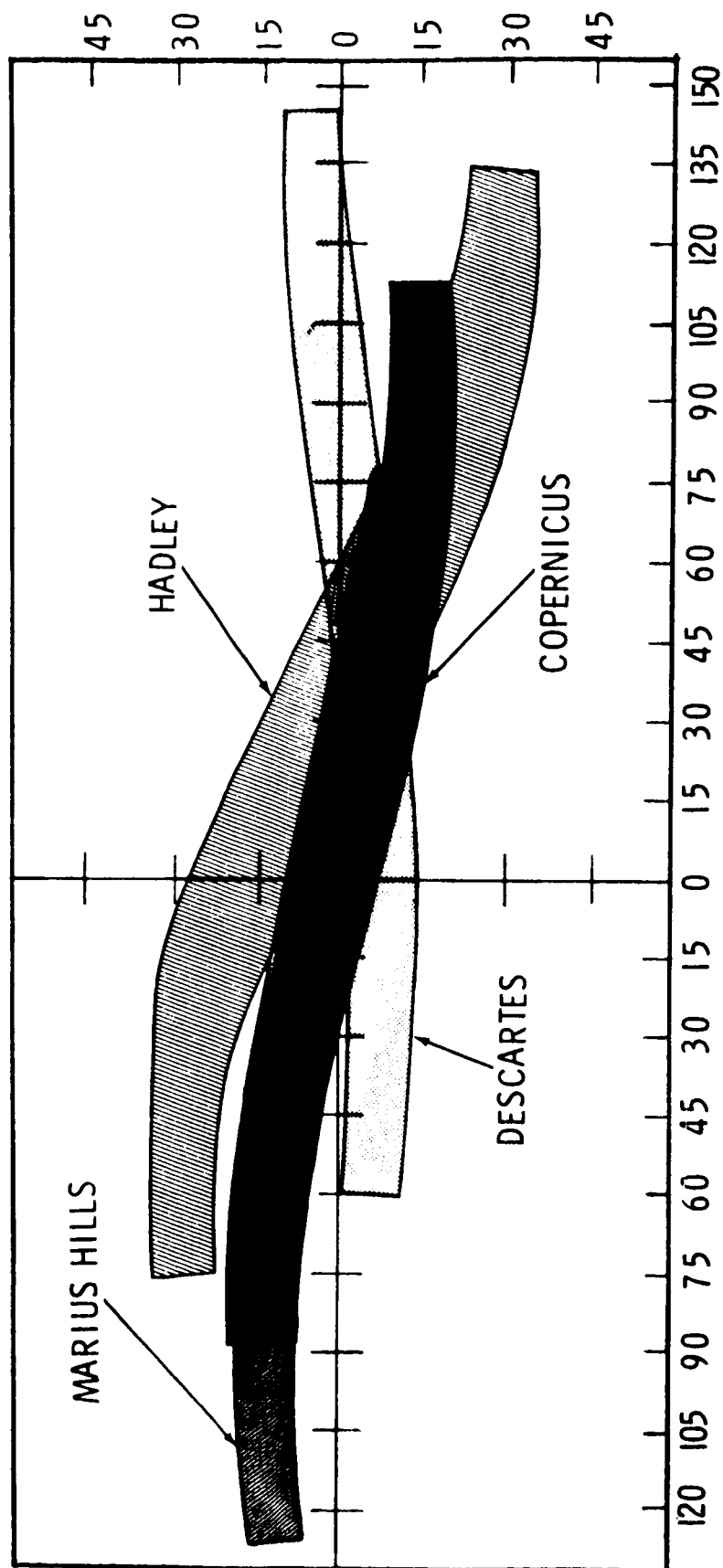


FIGURE 9

PHOTOGRAPHY

The most important photography is high resolution photography of the landing site. Together with low resolution stereo photography, topographical profiles can be derived and a model of a 5 x 10 mile area made for crew training in landmark recognition and visual acquisition of the landing spot. The approach terrain profile in the guidance computer may go back as far as 70 miles from the site, the accuracy required diminishing with range. Generally earth based photography is sufficiently accurate except for the last 20 miles of the descent, for which more accurate photography must be supplied. The photography is also essential for lunar surface traverse planning, in particular, LRV sorties.

Available Photography

Photography available for Copernicus peaks, and for Marius Hills is judged to be sufficient. Available high resolution photography for Hadley-Apennines does not include the landing point but is close enough to it to give sufficient confidence in its acceptability for landing. However, the quality of detailed traverse planning must necessarily suffer without the high resolution photography.

Present Descartes photography has been judged insufficient. The failure of Apollo 13 to photograph Davy Crater Chain leaves it in the same category.

Bootstrap Photography

Apollo 14 is scheduled for bootstrap photography of Descartes and of highland areas near Descartes.

An Apollo 15 mission to Marius Hills would permit photography of Davy Crater Chain, or of Descartes, or of highlands as far as 17° south, provided setting-sun illumination is acceptable, which seems to be true.

An Apollo 15 mission to Hadley-Apennines does not permit photography of either Descartes or Davy Crater Chain, or of the southern highlands.

While an Apollo 16 mission to Descartes would permit photography of Davy Crater Chain, the five-month interval of Apollo 16 makes its use difficult. Photography on Apollo 16 and 17 should be chosen for its own interest and for the time when the space program resumes exploration of the moon.

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Subject: Apollo Site Selection
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